

# Co-Simulation: Unlocking Advanced Approaches to Electrical Incident Analysis

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Julien Mécréant  
Schneider-Electric  
Grenoble  
France

Nicolas Choulet  
Schneider-Electric  
Grenoble  
France

Caroline Vollet  
Schneider-Electric  
Grenoble  
France

**Abstract** - Ensuring electrical reliability is key for Oil & Gas facilities, where process continuity and safety are essential. While outages are rare, when they occur, root cause identification is complex due to multiple interacting factors. Immediate restoration takes priority, leaving incomplete data for post-event analysis.

This paper illustrates how combining partial operational records - such as operator logs, alarm histories, and protection relay data - with advanced transient and dynamic simulations enables diagnosis of blackout causes and preventive actions. Through a case study of a generator fed installation, we show how the failure of a single breaker pole led to a full blackout, and how simulation confirmed the fault origin and guided the design of mitigation solutions.

In addition to technical insights, the paper presents best practices for integrating available protection relay data into co-simulation setups that combine electrical system modelling with protection algorithms and signal processing. Customer feedback is provided, as well as the contribution of this type of analysis to their understanding of incidents.

**Index Terms** - *Electrical Incident*, Blackout, Co-Simulation, Protection analysis

## I. INTRODUCTION

When a blackout occurs in an industrial facility with critical process, the top priority is to restore the installation - at least partially - as quickly and safely as possible. This restoration must ensure the protection of personnel and equipment, which requires a preliminary (even partial) understanding of the incident. Subsequent analyses refine this understanding to re-energize the entire facility, verify correct protection operation, prevent recurrence, and minimize consequences. Because such events often imply significant economic impact, structured analyses also support responsibility and liability assessment.

Initial investigations usually start with the operator: maintenance logs, monitoring and supervision data, and the records stored in measurement and protection relays. Relays act as "flight data recorders"; their disturbance files - voltages, currents, and digital I/O (Input/Output) - allow confirmation that relay behaviour matches the signals, that thresholds are consistent with actual electrical quantities, and help identify the electrical signature of the event.

For faults with limited consequences, analysing waveform data from a limited number of protection relays may be sufficient to pinpoint the root cause. For large-scale incidents, a system-level approach is required, including the collection of the SLD (Single Line Diagram), the operating mode at the time, and SCADA (Supervisory Control And Data Acquisition) event logs. In some cases, static, transient, or dynamic simulations are also necessary to validate or reject hypotheses, define corrective measures and assess the robustness and effectiveness of proposed mitigation solutions for the same root cause across different operating conditions - as was the case here.

## II. ELECTRICAL INSTALLATION DESCRIPTION

In 2025, a major electrical incident occurred on a vessel, resulting in a complete blackout. The ship main medium voltage switchgear supplies both final loads and propulsion (main drives and bow/stern thrusters). Although the final application differs, the electrical architecture shares many similarities with FPSO (Floating Production, storage and Offloading) installations: islanded generators and a critical requirement for supply continuity; a total loss of power introduces a drift risk and major safety hazards.

The vessel is powered by five medium-voltage DGs (Diesel Generators), each rated at around 20 MVA. The installation is divided into port and starboard; each composed of one half-busbar interconnected by a normally closed tie. Propulsion, harbour-manoeuving thrusters, and MV/LV (Medium Voltage / Low Voltage) transformer feeders connect on each half-busbar. Upon a failure on one side, the tie opens to feed the entire installation from the healthy side. Each generator neutral is grounded through a resistor limiting earth-fault current to 7 A per generator (resulting in 7 A to 35 A current limitation depending on the number of generators in service).

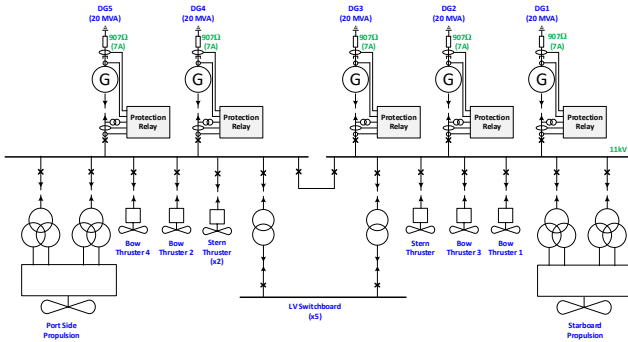


Fig. 1 Simplified single line diagram

Before the incident, four DGs were online (DG1 to DG3 on starboard side, DG4 on port side), one generator was offline (DG5 port side) and the tie was closed. The vessel had just left harbour.

**Event #1** - Day 1 - 00:00: Immediately after leaving harbour, DG4 tripped on ANSI 67N (directional earth-fault). Since only DG4 protection operated, operators inferred a fault on generator side.

On each generator feeder, a ANSI 67N directional earth fault protection is implemented to monitor the presence of ground faults on the generator side. Fault direction is determined using the residual current - measured by a core-balance current transformer (CBCT) installed on the generator incomer cables - and the residual voltage, calculated from the phase-to-ground voltages measured by voltage transformers (VTs).

In the event of an earth fault on generator DG4 (left-hand generator in Fig. 2), two main contributions to the earth fault current coexist: the first contribution originates from the earthing of generator DG4 itself. This fault current component is not measured by the DG4 ANSI 67N protection. The second contribution originates from the earthing of the other generators in the system (denoted DGx in Fig.2). The additional contribution of the network capacitive current (not represented on Fig. 2) could also be considered.

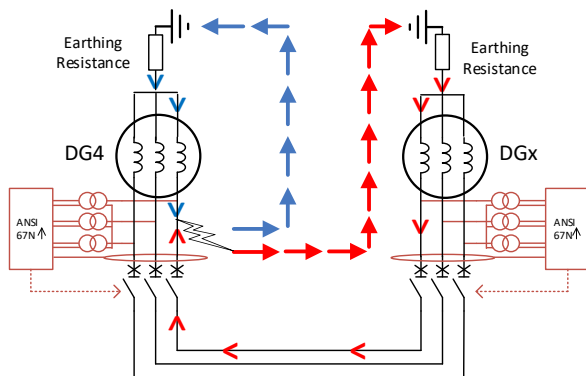


Fig. 2 Earth fault current circulation

As a result, the CBCT on each DGx cables detects the residual current corresponding to its own earthing contribution, while the CBCT of generator DG4 detects the

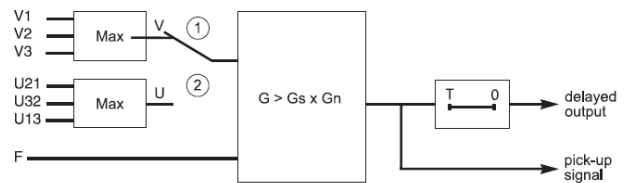
residual current resulting from the combined contribution of all the other generators DGx.

Since the directional element is set with a direction toward the generator, only the DG4 ANSI 67N operates. This ensures selective tripping with the other generators, thereby maintaining continuity of service for the remainder of the installation: the remaining generators took over DG4 load smoothly. Then DG5 was started and connected, and the installation ran normally for more than 13 hours, suggesting the situation was under control.

**Event #2** - Day 1 - 13:00: Given the reduced load and stable operation, DG1 was intentionally shut down.

**Event #3** - Day 1 - 13:04 to 13:07: The three remaining generators (DG1, DG2 and DG3) tripped sequentially within around 3 minutes leading to a full blackout of the vessel. In all cases, the active protection was ANSI 24 (overfluxing).

ANSI 24 protects generators, motors, and transformers against core heating due to saturation. Such saturation may occur when the voltage applied to the equipment terminals becomes too high, when the system frequency decreases, or when a combination of high voltage and low frequency takes place. Overfluxing protection therefore compares the measured V/f (Voltage/frequency) ratio at the equipment terminals with a predefined pickup threshold, associated with a time delay, as illustrated in Fig. 3 below:



where  $G = U/f$  or  $V/f$  depending on machine coupling  
 $G_n = U_n/f_n$  or  $V_n/f_n$  depending on the voltage  
 $G_s$  = the set point

- ① phase-to-neutral voltage
- ② phase-to-phase voltage

Fig. 3 example of ANSI 24 block diagram

Three tripping philosophies can then be applied: constant-time tripping - where the tripping time remains the same regardless of the measured V/f ratio - or inverse-time tripping - where the tripping time becomes faster when the V/f ratio significantly exceeds the threshold defined by the user - or a combination of both curves. Fig. 4 below illustrates definite time and inverse-time curves. The horizontal axis represents the voltage-to-frequency ratio (V/Hz), while the vertical axis represents the protection operating time.

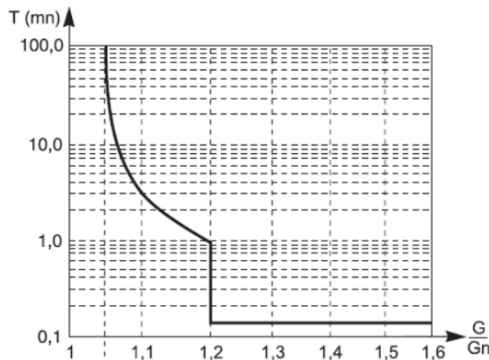


Fig. 4 ANSI 24 – combination of inverse-definite time and definite time tripping curve.

Acceptable flux densities for generators are partially guided by IEC 60034-1 as shown in Fig. 5 below.

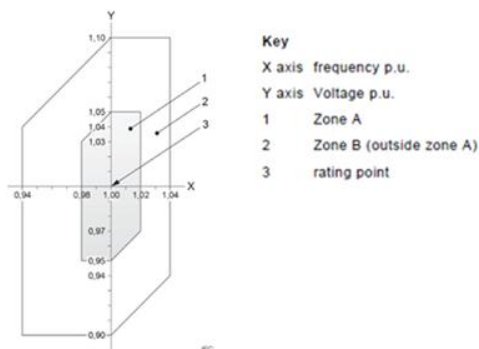


Fig. 5 Extract from IEC 60034-1 Rotating electrical machines - Rating and performances [1]

According to this standard, generators must operate continuously in Zone A, whereas operation in Zone B shall be time limited. Acceptable duration is not given and depends on generators characteristics, however in practice, detailed information required is rarely available. As a result, a combination of IDMT (Inverse Definite Minimum Time) and DT (Definite Time) curve is generally used, as per Fig. 4. The tripping time is typically on the order of several minutes when the voltage-to-frequency ratio exceeds 110% of its nominal value and decreases to several seconds when ratio exceeds 120%.

Despite its relevance for equipment protection, ANSI 24 overexcitation (V/Hz) protection remains relatively unfamiliar to plant operators. Unlike short-circuit or earth fault protections, which are directly associated with clear fault conditions, overexcitation protection operates under abnormal but non-fault operating scenarios and with relatively long-time delays. As a result, its function, operating principle, and associated alarms or trips are not always well understood in daily operation.

As this trip (Event #3) occurs shortly after the intentional disconnection of generator DG1 (Event #2), maintenance personnel may initially interpret the event as a load transfer issue between the disconnected generator DG1 and the three remaining generators. Such a scenario could, for

example, be associated with an excessive frequency drop following the redistribution of load.

Since the root cause of the incident is not clearly identified and given the urgent situation resulting in a total blackout, maintenance personnel decided to split the installation into two electrically independent sections and to disconnect all MV feeders in order to maximize the likelihood of restoring power - at least partially - to the installation.

**Event #4** - Day 1 - 13:13: Reconnection attempts. The Ship is in total blackout for five minutes. Starboard generators (DG1, DG2 and DG3) were connected individually; each tripped-on ANSI 24 in less than 2 minutes, regardless of the machine. Then the operators try to connect the three starboard generators (DG1, DG2, and DG3) nearly simultaneously instead of sequentially; the system remained energized long enough to progressively restore loads. Forty minutes later, following a planned load decrease, DG1 was intentionally shut down; DG2 and DG3 tripped around 1 minute later on ANSI 24. Following this new blackout, DG5 was then connected to the port side and re-energized propulsion and critical loads without issue. Again, the behaviour pointed to a systemic issue rather than a defect on a single generator.

**Event #5** - Day 1 - 22:00: With port distribution restored by DG5 only (DG4 previously tripped on earth-fault – Event #1), starboard outgoing MV breakers were racked out then reinserted one by one. During reinsertion of Bow Thruster #1, a voltage fluctuation was observed although the breaker remained “open”. Inspection revealed one pole was closed while the two others were open. After permanently disconnecting Bow Thruster #1, both sides were re-energized without further trips. The origin of the blackout seems to be identified. Then, combined data review and co-simulation confirmed that the overfluxing trips were consistent with single-phase energization of the thruster load.

In summary, the electrical installation appears to have experienced two successive and seemingly unrelated electrical disturbances. The first event, which had no significant impact on the installation, is likely a ground fault on DG4. The second event, which resulted in multiple consecutive blackouts, was triggered by the operation of the generators’ ANSI 24 overfluxing protection. With the sequence of events now established, the next step is to analyse the root causes of these disturbances, beginning with the activation of the ANSI 24 overfluxing protection.

#### IV. POST-EVENT ANALYSIS OF OVERFLUXING (U/F)

The following figure shows the voltage and current waveforms captured by DG1 protection relay during one of the unsuccessful reconnections attempts after a full blackout (Event #4). All the MV loads are disconnected.

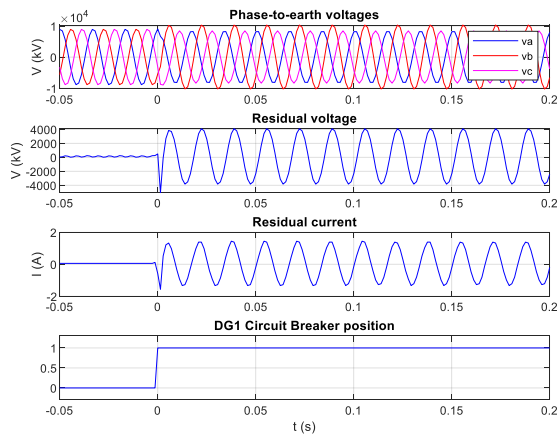


Fig. 6 DG1 relay waveforms during an unsuccessful reconnection

Voltages were measured on the generator side (upstream of the breaker). Before  $t = 0$ s, the generator was not yet connected, and the phase-to-earth voltages were balanced and equal to the rated voltage. At  $t = 0$  s, closing onto the busbar caused phases 1 and 3 amplitudes to decrease while phase 2 increased. Measured frequency remained stable and cannot explain ANSI 24 operation.

A residual current of around 0.94 A (vs. 7 A earthing per generator) and a residual voltage appeared at closing, which could suggest a resistive earth fault. However, in a usual single phase-to-earth fault, only the faulted phase drops while the healthy phases rise towards line-to-line; this was not observed. A double earth fault (also called cross-country fault) could have this pattern, but it would require both faults to be very high impedance - unlikely with all MV feeders disconnected.

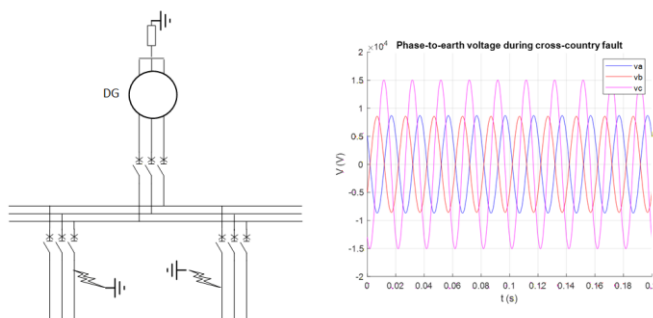


Fig. 7 Schematic double earth fault and voltage signature

Since common root causes do not explain the recorded waveforms, the impact the bow thruster circuit breaker partially closed could match with signals measured.

#### Theoretical approach

At first glance, a simplified motor model fed on one phase only cannot alone explain the phenomenon: unenergized phases would not carry current without a return path, so zero-sequence voltages cannot appear at the breaker primary. But the consideration of parasitic phase-to-earth capacitances provides a consistent explanation.

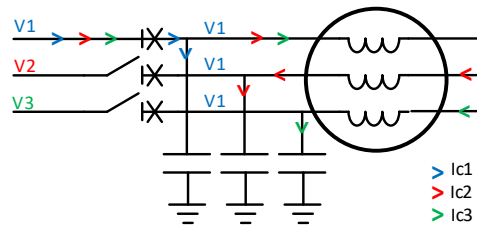


Fig. 8 Motor equivalent electrical circuit

Each parasitic capacitance is charged to the same voltage  $V_1$ . The resulting per-phase current is as follow.

$$I_c = C \cdot \omega \cdot V_1$$

The total current through the circuit breaker is then as follow.

$$I_{total} = 3 \cdot C \cdot \omega \cdot V_1$$

This residual capacitive current could then induce a residual voltage like an earth-fault signature.

Simplified theoretical approach based on symmetrical component [2] has been done to check the order of magnitude of the phenomenon. The equation used are the following one:

$$I_1 = \frac{3E}{Z_d + Z_i + Z_o + 3Z}$$

$$V_1 = 3Z \frac{E}{Z_d + Z_i + Z_o + 3Z}$$

$$V_2 = a^2 E \left( 1 - \frac{Z_d + a^2 Z_i + a Z_o}{Z_d + Z_i + Z_o + 3Z} \right)$$

$$V_3 = a E \left( 1 - \frac{Z_d + a Z_i + a^2 Z_o}{Z_d + Z_i + Z_o + 3Z} \right)$$

$$I_o = \frac{E}{Z_d + Z_i + Z_o + 3Z}$$

$$V_0 = -Z_o \left( \frac{E}{Z_d + Z_i + Z_o + 3Z} \right)$$

With,

$V_1, V_2, V_3$  = phase to earth voltage of phase 1, 2 and 3.

$I_1$  = faulty phase current (A)

$I_o$  = zero sequence current (A)

$V_o$  = zero sequence voltage (V)

$Z$  = fault impedance (in  $\Omega$ )

$Z_d$  = positive impedance of the electrical system ( $\Omega$ )

$Z_i$  = negative impedance of the electrical system ( $\Omega$ )

$Z_o$  = zero sequence impedance of the electrical system ( $\Omega$ )

$E$  = rated phase to earth voltage of the system (V).

$a = e^{2i\pi/3}$

The positive and negative sequence impedance  $Z_d$  and  $Z_i$  of the circuit mainly depends on number of generators connected and their electrical characteristics since there is neither long cable nor transformer between the source and the bow thruster motor. The zero sequence impedance  $Z_o$  mainly depends on the earthing resistance of each generator connected. The fault impedance  $Z$  is replaced by the equivalent impedance composed of the 3 motor parasitic capacitances in parallel: the "equivalent fault current" goes to the earth through the three parasitic capacitances (one per phase).

In first approach, positive and negative impedances could be neglected compared to zero sequence impedances. The previous equations are simplified as follow.

$$I_1 = \frac{3E}{Z_o + 3Z} \quad V_1 = 3Z \frac{E}{Z_o + 3Z}$$

$$V_2 = a^2 E \left( 1 - \frac{aZ_o}{Z_o + 3Z} \right) \quad V_3 = aE \left( 1 - \frac{a^2 Z_o}{Z_o + 3Z} \right)$$

$$I_o = \frac{E}{Z_o + 3Z} \quad V_0 = -Z_o \left( \frac{E}{Z_o + 3Z} \right)$$

The parasitic phase-to-earth capacitance of the motor was known (around 0.135µF per phase – value previously measured during factory acceptance tests of the thrusters) as well as the earthing resistance (907Ω per generator). It was then possible to compare theoretical approach with the field result as shown in the next table for an operating mode with one generator connected only (DG1 – Event #4).

TABLE I  
COMPARISON BETWEEN SIGNAL MEASURED AND THEORETICAL APPROACH

	Ir (A)	V1 (kV/pu)	V2 (kV/pu)	V3 (kV/pu)	Vr (kV)
Theoretical results	0.96	6.3/0.99	7.2/1.13	5.7/0.9	2.6
Field results	0.94	6.0/0.94	7.3/1.15	6.0/0.94	2.8

The order of magnitude is similar between theoretical approach and field results – same level of residual current, one phase-to-earth voltage higher than the rated phase-to-earth voltage (6.35kV) and two phase-to-earth voltages lower than the rated voltage. The result difference comes from the simplified assumption considered for the end calculation. For instance, cables are neglected whereas healthy feeder's capacitance cables also contribute to the current circulation and to the neutral voltage displacement.

#### Co-Simulation Approach

In order to get more accurate result and to evaluate the impact on the ANSI 24 protection, a portion of the network was modelled in EMT-ATP power systems software. The EMT-ATP model is presented in Fig. 9.

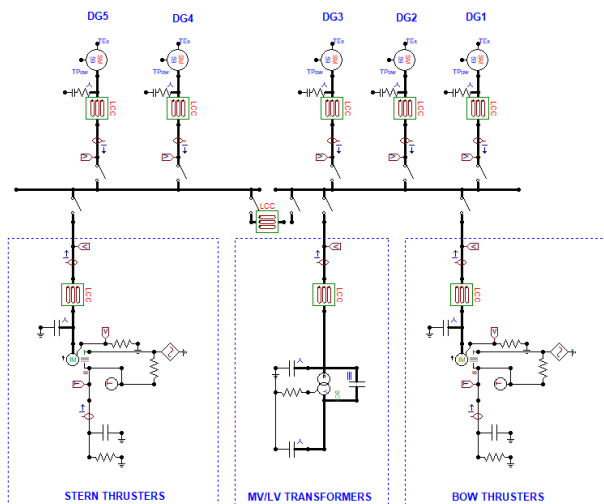


Fig. 9 Schematic diagram on EMT-ATP power systems software

All main electrical parameters were known, making the analysis possible. The partially open thruster breaker was represented with one pole closed and two poles open. Simulated quantities are compared with field measurement. (Fig. 10).

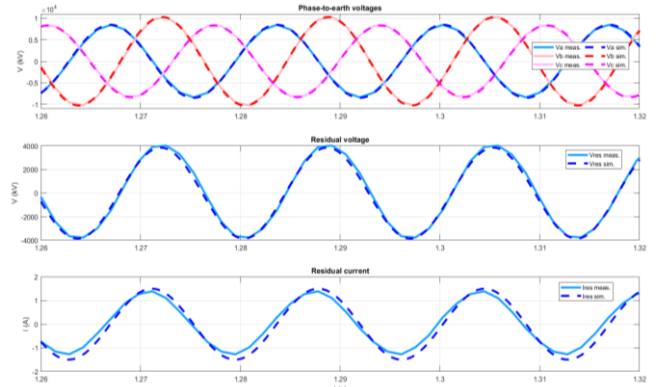


Fig. 10 Comparison between simulations and real signals

This confirms both the correctness of the physical understanding of the phenomenon and the validity of the simulated model. The next step consists in verifying that the ANSI 24 protection operates consistently with the measured signals for all the operating modes.

The EMT-ATP simulated signals were then fed to a MATLAB digital model including CT (Current Transformer) & VT sensors models, acquisition chain of the protection relay (hardware, Analogue-to-digital conversion, Digital signal processing (numerical filtering, Harmonic 1 calculation...) and protection algorithm and tripping logic (especially ANSI 24 protection for this case).

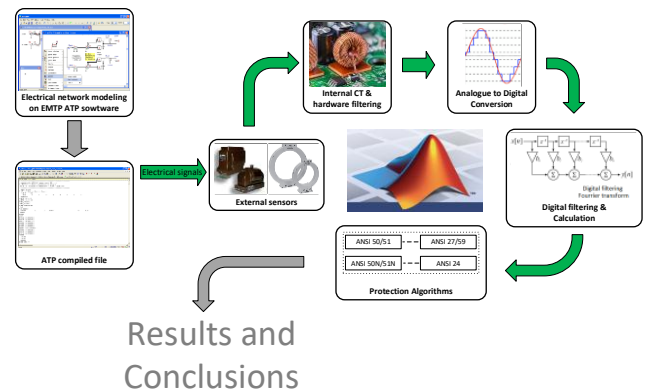


Fig. 11 EMT-ATP & Matlab co-simulation principle

Simulated tripping times were compared with customers logs and fault recordings to check the consistency when attempting to reconnect single generator.

TABLE II  
COMPARISON BETWEEN SIGNAL MEASURED AND SIMULATION APPROACH – 1 DG CONNECTION ATTEMPT

	Ires (A)	U/f (%)	Tripping time
Simulation results	1.0A	113.2	From 1'20" to 2'22"
Field results	From 0.9A to 1.1A	From 113 To 116.8	From 1'15" to 1'40"

The numerical model of the protection relay considers the accuracy of the overfluxing protection. Minimum and maximum tripping time are then given in Table II. Except for the minimum tripping time which is slightly lower in the field than in simulation, co-simulation results are accurate and confirms that protection relay act as expected: the partial opening of the circuit breaker induces a voltage increase of one phase-to-earth voltage. Then, U/f ratio of the ANSI 24 overfluxing protection is exceeded and led to generator protection trip. The minimum tripping time is overestimated because simulated U/f ratio is slightly underestimated. By applying the maximum field U/f ratio in the digital twin of the protection relay, the tripping time obtain is between 59s and 1min29s, value complying with the field result.

The co-simulation analysis is then extended to better understand why the ANSI 24 protection operated under some configurations (e.g., single generator online, all loads disconnected) but did not operate in others (e.g., normal operation with four generators running). These simulation results are key to have a full understanding of the phenomenon because field information were missing for some events. For instance, Event #3 recording files had been overwritten during the restoration process - protection relays only retain a limited number of disturbance records. The table below gives the tripping time for the different number of generators connected.

TABLE III  
ANSI 24 SIMULATED TRIPPING TIME DEPENDING ON NUMBER OF GENERATORS CONNECTED

Number of DGs	U/f (%)	Min Trip time	Average Trip time	Max Trip time
x1	113	1'20"	1'42"	2'22"
x2	107	3'30"	8'2"	No Trip
x3	104	8'20"	No Trip	No Trip
x4	103	30'24"	No Trip	No Trip
x5	102	No Trip	No Trip	No Trip

When several generators are connected, the U/f ratio decreases and approaches the asymptote of the IDMT curve (105%). The tripping time becomes more difficult to predict. The simulated network and relay models also allowed verification that other configured protection functions behaved as expected: ANSI 51N Maximum residual current protection and ANSI 59N Maximum residual voltage protection did not trip because residual current / voltage

remains lower than the thresholds; ANSI 27 undervoltage protection did not trip because the undervoltage was lower than the threshold; ANSI 59 overvoltage protection did not trip because phase-to-phase voltages are monitored and only phase-to-earth voltages are impacted by this event.

## V. ANALYSIS OF GENERATOR EARTH-FAULT TRIP (EVENT #1)

DG4 tripped on directional earth-fault overcurrent following the opening of the bow-thruster breaker, which remained energized on one polarity. Relay recordings were examined to determine whether DG4 truly saw a phase-to-earth fault or if this was a secondary effect of the incomplete opening of bow thruster CB (Circuit Breaker).

Available residual-current measurements were, as shown on Fig. 12: (i) numerical sum of the three phase CTs (inaccurate with 1000/1 CTs), (ii) neutral earthing resistor CT (for ANSI 51N), and (iii) a Core-Balance CT (CBCT) around the generator incomer cables (used for ANSI 67N directional earth fault protection, set on generator direction).

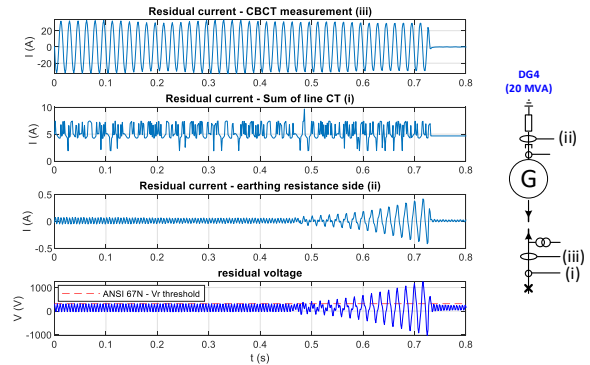


Fig. 12 DG4 recording file during earth fault tripping

At the beginning of the record, the core-balance CT measured around 20 A residual current while residual voltage was negligible (measurement accuracy only). Given the neutral earthing system (7A per generator connected – 4 generators connected), 20 A residual current would imply a solid earth fault, with residual voltage near three times the rated phase-to-earth voltage. The measurement inconsistency is typical of a core-balance CT installation issue. Most often, cable screen earth braids do not pass correctly through the CBCT (omitted or reversed). Screen currents (including induced current) are not balanced on the three phases and are proportional to the phase current. It could create a false residual current if the screen is not properly pass through the CBCT as shown in Fig. 14.

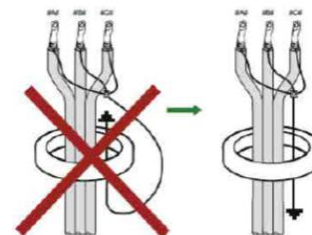


Fig. 14 earthing braids connection across CBCT

At the same instant, the phase-sum residual current was around 0 A (only noise is measured with a level consistent with 1000/1A CT ratio) and no current is measured through the CT installed at the neutral earthing resistance side, confirming a wiring/installation problem on the CBCT. Until then, the problem had no operational impact: although the false residual current exceeded the ANSI 67N current pickup (set to 2 A), the residual voltage was below 2%  $V_{LL}$  (Line to Line voltage) (as shown in Fig. 12). When the bow-thruster breaker opened on two polarities, residual voltage appeared and ANSI 67N tripped spuriously.

## VI. RESULTS PRESENTATION AND ADDITIONAL ANALYSIS

The analysis of the recordings was carried out in parallel with the investigations carried out on the vessel, as soon as the required information became available. Preliminary conclusions were quickly provided to the client to support the understanding of the phenomenon.

Subsequently, to gain further insight into such an event and to develop potential protection schemes capable of detecting a partial circuit-breaker opening, additional simulations were performed considering any circuit breaker in the installation as potentially failing. In the case of a generator circuit-breaker failure, the phenomenon produces highly atypical voltage signals (Fig.15), significantly different from the scenario in which the bow-thruster circuit breaker remained conducting on one phase. Among other aspects, the voltages exhibit oscillatory behaviour, the residual current amplitude is not constant, and it exceeds the pickup threshold of the ANSI 51N protection implemented on the generators.

Such simulations always require a critical assessment of the obtained results. The way each component is modelled can indeed lead to inaccurate outcomes and/or misinterpretation of the underlying phenomenon. This is particularly true for this event, where the phase-voltage fluctuations do not appear to be realistic. To remove any ambiguity regarding the validity of the simulation results, complementary laboratory tests were conducted on a reduced equivalent network. The behaviour was successfully reproduced, as illustrated in the Fig. 16.

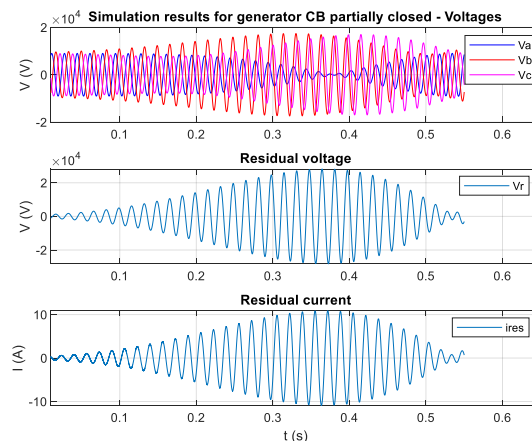


Fig. 15 Electrical network behaviour in case of generator CB partial opening – simulation results.

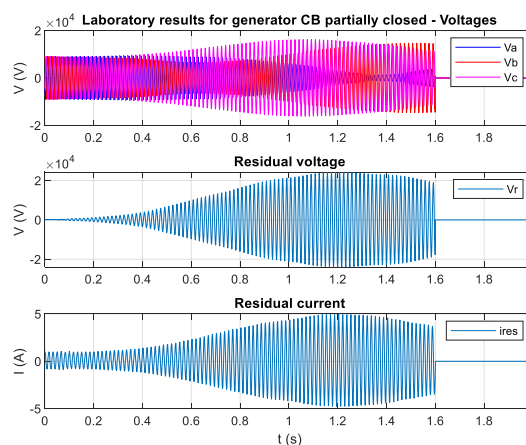


Fig. 16 Electrical network behaviour in case of generator CB partial opening – laboratory results.

This additional analysis not only made it possible to define the complementary protections to be implemented but also increased our level of confidence in the simulation of an atypical case leading to unconventional phenomena.

More generally, such simulations require a critical eye; modelling choices can mislead or obscure the phenomenon. Without field records or laboratory test, an isolated simulation of this incident might have been deemed unrealistic. Here, we reassured the client on the event sequence and increased confidence in modelling an atypical case leading to atypical behaviour.

## VII. CONCLUSIONS

The combined analysis of the blackout - using SCADA, relay recordings, and EMT (ElectroMagnetic Transient) simulations - confirmed the root cause of an atypical event whose consequences initially looked random: a several-minute blackout caused from one pole of a circuit breaker remaining closed during opening and incorrect installation of earth braids inside a CBCT. A clear understanding of the phenomenon and system behaviour enabled: (i) confirmation that protections operated as intended; (ii) identification of a common point of failure in overfluxing logic (prioritize tie-breaker tripping to preserve one side before tripping generators); (iii) a revised overfluxing philosophy using line-to-line rather than line-to-neutral sensing, since phase-to-phase voltages (and magnetic flux) are not affected by phase-to-earth imbalance; (iv) implementation of an alarm for partially open breakers considering feeder/incomer architecture impacts on residual quantities. Practically, system analyses are significantly enhanced when disturbance records are automatically captured by supervision systems. Likewise, electromagnetic transient (EMT) studies become more efficient and reliable when based on an up-to-date network model. Periodic review of relay event recordings, even in the absence of incidents, plays a key role in preventing major disturbances and accelerating the implementation of corrective actions. In the present case, such a preventive review would have identified the incorrect installation of DG4 core-balance CT and prevented the initial trip.

Beyond incident analysis, these practices also contribute to reinforcing data management discipline among operators and to developing a deeper understanding of the electrical system among personnel responsible for diagnostics.

## VIII. REFERENCES

[1] IEC 60034-1, Rotating Electrical Machines - Rating and Performance.

[2] Cahier technique n°18, Schneider Electric – Analysis of three-phase networks in disturbed operating conditions using symmetrical components.

## IX. VITA

**Julien Mécréant** graduated from the National Polytechnic Institute in 2011 with a degree in electrical engineering. He joined Schneider Electric the same year as an Electrical Engineer, where he has been working on electrical network analysis for industrial power systems. His activities include on-site customer measurements for power quality assessment and transient event analysis. He has also been involved in the development of protection function algorithms for electrical protection systems. He is currently a Principal Engineer specializing in power systems and actively contributes to the resolution of critical technical

issues occurring at customer sites, providing expert support for complex electrical incidents.

[julien.mecreant@se.com](mailto:julien.mecreant@se.com)

**Nicolas Choulet** graduated from Université of Joseph Fourier in 2014 with a master's degree in electrical engineering. He joined Schneider Electric in 2021, where he has been working on electrical network analysis for industrial power systems. His activities include static, dynamic, and transient power systems analysis.

[nicolas.choulet@se.com](mailto:nicolas.choulet@se.com)

**Caroline Vollet** received her Electrical Engineering degree from the National Polytechnic Institute of Grenoble in 1988. She joined Merlin Gerin (now Schneider Electric) in 1988. She is currently working on electrical network analyses such as stability, harmonic and overvoltage studies. She has been personally involved in several instances of equipment failure or malfunctioning in different kinds of industrial plants.

[caroline.vollet@se.com](mailto:caroline.vollet@se.com)